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GRAVITY AND ACOUSTIC WAVES APPLIED TO THE DYNAMICS AND KINEMATICS--ETC(U)

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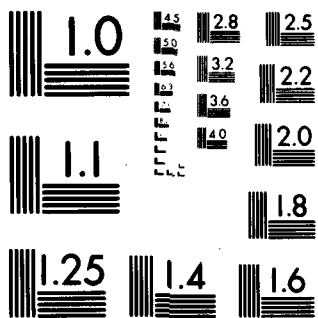
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A generalized review of the work accomplished in the direct and spin-off areas supported over the past six years in the following areas is presented: 1) Use of Infrasound as an Atmospheric Probe: Infrasonic signals from natural and artificial sources were used as a passive probe of the atmosphere. 2) Gravity Wave Program: In this study, an array of sensitive microbarographs (microbarovariographs) is used rather than microphones. Results so far show that surface gravity waves are related to the presence of wind shear aloft and often constitute			

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20. ABSTRACT CONTINUED

➤ continuous background perturbations. Gravity waves were also shown to characterize the approach of warm fronts aloft, often well before the advent of precipitation and other storm features. Gravity waves were also shown to be of possible importance in generating thunderstorms through the triggering action at times of unstable or conditionally unstable conditions.

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FINAL TECHNICAL REPORT

Grants: DAAG 29-74-G-0172 and DAAG 29-77-G-0131

Title of Projects: Gravity and Acoustic Waves Applied to the  
Dynamics and Kinematics of the Atmosphere

Principal Investigator: W. L. Donn

Co-principal Investigator: N. K. Balachandran

Note: By letter of 21 June 1977, permission was granted by Jack L. Harless to submit a single final report covering both three-year grants because they were essentially a continuous research program.

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### Summary of Scientific Results:

The complete details of our scientific results during the six years of the two grants are given in the publications listed following this narrative. A second list of all scientific presentations at regular or invited meetings which resulted in published reports or abstracts is also given.

A fairly detailed summary of work was provided in the eleven semiannual reports issued during the regular tenure of the two grants. The following is thus a more generalized review of the work accomplished in the direct and spin-off areas supported by the projects.

#### 1. Use of Infrasound as an Atmospheric Probe

After identifying the atmospheric factors controlling the propagation of infrasound we inverted the procedure to use infrasonic signals from natural and artificial sources as a passive probe of the atmosphere. The procedure we established is based on the application of Snell's Law to acoustic ray geometry and depends on the fact that when sound travels upward into the atmosphere it will undergo internal reflection from refraction in a region where the acoustic speed in the direction of propagation equals or exceeds that at the surface. With the use of arrays of tuned microphones, we can compute the horizontal trace velocity of infrasound returning to the surface after reflection aloft and we have shown that this measured trace velocity equals the acoustic velocity in the direction at the reflection level. The reflection velocity is the sum of the normal acoustic speed that is dependent on

temperature and the wind speed in the direction of propagation (or  $C+w$ , where  $C$  is the normal sound speed and  $w$  the wind component in the propagation direction.) As we know, the temperature structure from either climatology, rocket soundings or satellite observations, we obtain  $w$ , the wind component by subtraction of  $C$  from the trace velocity  $V$  or  $w = V - C$ . Natural sound sources were primarily interfering ocean waves that radiate nearly continuous atmospheric infrasound in the period range of about 4 to 6 seconds. This background infrasound in the atmosphere provides a continuous monitor of winds in the stratosphere and thermosphere. Inter-and intra seasonal variations of these regions are revealed on a real time basis. Stratospheric warmings in the region of study have been detected as soon as any associated wind reversal occurs. We have also shown that the absorption of this background infrasound in the lower thermosphere could have a strong influence on the heating of this region. Our observations of wind speeds agree well with those from the Wallops Island meteorological rockets. Similar agreement was obtained from an acoustic array at College, Alaska installed by C. Wilson who developed this program in cooperation with Lamont.

Background infrasound from sea waves has provided an excellent, continuous monitor of the regional behavior of atmospheric tidal winds-both direction and speed. Strong semidiurnal tides are present during non-summer months at least 70 percent of the time and are revealed by a prominent increase in sound amplitude caused by strong tidal wind

reinforcement of the sound channel. A prominent diurnal tide has been shown close to 50 percent of the time by the same amplitude effect.

More sporadic natural infrasound is generated within thunderstorms and our observations have been shown to support the theory that such signal results from the charge collapse within the cloud following lightning strokes.

Infrasound of regular occurrence was also discovered from the several Concorde SSTs flying to both Dulles and J.F.K. International airports. We showed that sound generated by the planes' shock waves followed the same propagation behavior as that for natural infrasound but had the advantage of originating in a known location at a known time. Behavior of this mode of infrasound resulted in some very detailed stratospheric and thermospheric analyses.

## 2. Gravity Wave Program

In this study an array of sensitive microbarographs (microbarovariographs) is used rather than microphones. Results so far show that surface gravity waves are related to the presence of wind shear aloft and often constitute continuous background perturbations. We investigated the possibility that such background activity might provide a means of withdrawing small, but significant, amounts of kinetic energy and momentum from the circulation. Although suggestive, results are inconclusive.

Gravity waves were also shown to characterize the approach of warm fronts aloft, often well before the advent of precipitation and other storm features. We showed that a change to strong wave activity could have prognostic use for east coastal cyclones in particular because their development is often not well-observed by standard synoptic observation tools.

Dravity waves were also shown to be of possible importance in generating thunderstorms through the triggering action at times of unstable or conditionally unstable conditions.

#### Government Relevancy

Our data and interpretations have often been of specific value to various military and civil agencies. Some examples are summarized below:

##### 1. Electronic Warfare Division: ECOM, U.S. Signal Corps

For years this division of the army maintained long-range acoustic monitoring of many artificial events. Many anomalies of signal occurrence as well as signals were reported. We were able to show that occurrence anomalies were due to temporal changes in high level winds that either reinforced or destroyed the sound ducts. In the case of strange signals, we were able to identify most of the sources and explain their characteristics.

##### 2. East-coast booms

During the winter of 1976-77 and February 1975 parts of the east coast was sporadically affected by strong low-frequency sound. Because of our acoustic arrays, which have been in

continuous operation for many years and the knowledge gained in interpretation we were able to render considerable aid in the investigation of this problem and its solution.

### 3. Ballistic missile detection

Through our scientific studies of the coupling of shock waves from Apollo rockets to seismic waves in the earth, we were able to assist the Huntsville Missile Defense Command in the evaluation of this procedure as an alert tool.

### 4. Nuclear test Alert 747: September 1979

As a result of expertise gained in the interpretation of anomalous signals generated in the atmosphere, the P.I. was placed on a White House panel of eight scientists assembled to examine and evaluate a diverse assemblage of information bearing on this event. Many long meetings were held and a final report has just been prepared. (Dec. 4, 1980)

### Personnel Supported

The following scientific and technical personnel were supported all or in part and at different times, during the tenure of the two grants.

William L. Donn

Nambath K. Balachandran

Mary Alice Austen

Bernard Gallagher

Educational Benefits

One student, David Rind, acquired a Ph.D. degree, made possible by the laboratory support from the two grants. Other students who received varying degrees of training under the support made possible were:

Brian Brenner

Scott Davis

Lawrence Spiegel

Robert Towsley

Robert Rilling

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